# SCIENCE

NEW SERIES
VOL. LVII, No. 1475

FRIDAY, APRIL 6, 1923

ANNUAL SUBSCRIPTION, $6.00
SINGLE COPIES, 15 CTS.

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Vol. LVII APRIL 6, 1923 No. 1475





**SCIENCE: A Weekly Journal devoted to the Advancement of Science, publishing the official notices and proceedings of the American Association for the Advancement of Science, edited by J. McKeen Cattell and published every Friday by**

**THE SCIENCE PRESS**

**100 Liberty St., Utica, N. Y. Garrison, N. Y.**
**New York City: Grand Central Terminal**

**Annual Subscription, $6.00. Single Copies, 15 Cts.**

**Entered as second-class matter January 21, 1922, at the Post Office at Utica, N. Y., Under the Act of March 3, 1879.**


## THE LIFE CYCLE OF THE PROTOZOA[1]

THE obligation which this occasion brings offers a challenge to the zoologist whose pleasant privilege it is to address you, to summon from his experience his ripest judgment upon the problems of greatest interest in his field of investigation. It affords him the opportunity to round up his vagrant ideas, to corral his scattered observations and to brand them with the symbols which we all recognize. He must therefore leave the specialized field in which he ranges and come into the arena of our common and central problems.

The Protozoa, according to our generally accepted view of the evolution of the animal kingdom, stands at the base of the animal tree of life. From them have sprung, perhaps in a polyphyletic fashion, the other phyla. The structure of the collar cells of the Porifera suggests the origin of this phylum from the Choanoflagellata. The occurrence of nematocysts, tentacles and eyespots in the Dinoflagellata turns our attention from them to the Cœlenterata, while some ciliates and the platyhelminthes have much in common. Be this as it may, the Protozoa are found in the oldest fossiliferous rocks, and the genera of Radiolaria therein conform rather closely to genera living to-day, while the fossil Dinoflagellata of the flints of Delitzsch are scarcely distinguishable from species living in the modern seas. The striking similarities of the most ancient fossil Protozoa to recent ones afford some ground for the inference that the Protozoa living to-day differ but little from those when life was young. We may therefore turn to this group with some confidence that the phenomena which we discover therein to-day are

[1] Vice-presidential address before Section F—Zoology of the American Association for the Advancement of Science and presidential address before the American Society of Zoologists at Boston, December 27, 1922.

both significant and instructive as to form, structure and function, when the waters of the primitive seas formed the first balanced aquarium.

The Protozoa appear to have emerged at that level in the evolution of living substances in which the nucleus was being established, superseding the phase of distributed chromatin and substituting a permanent organization of chromatin within a nuclear membrane for the temporary aggregation of chromatin granules at certain critical stages in the life cycle, such as division. While it is as yet too early in the period of the cytological exploration of the Protozoa to conclude that the evolution of chromosomes first took place in this group of animals, it does seem highly probable that this is true and quite probable that most Protozoa have definite nuclei and that they have chromosomes and that they conform in principle to the basic features of mitosis in the Metazoa and Metaphyta.

The seeming exceptions to this conclusion which we find in accounts of the *de novo* origin of nuclei from chromidia lack adequate cytological evidence and are in my opinion based upon false interpretations of cytoplasmic contents and conditions resulting from the cycle of metabolism in part, and, in a few reported instances, are based upon undetected parasitic infections. Our confidence in the conformity of the Protozoa to the integrity of and descent of nuclei and in the individuality of chromosomes which we find in the Metazoa, increases steadily as sound cytological investigation of the group progresses. We may therefore infer that the Protozoa have a cellular organization and are equipped with the essential structural basis for the mechanism of heredity, in so far at least as the possession of chromosomes, mitosis and even chromomeres and also genes are concerned.

With the presence of this equipment established in the group we may well ask in how far these supposedly simple organisms have also taken on the complicated life history of the Metazoa and Metaphyta. It is to several aspects of this question that we will turn our attention more closely this evening.

The searcher for the origins of biological phenomena will find the Protozoa a fertile but perplexing field for their discovery. Here have arisen all the fundamental types of symmetry, spiral, both leiotropic and dexiotropic, radial, bilateral and a host of modifications of these. Here also are several distinct types of mitosis, different locations of the centrosome, extraordinary derivatives of this organ ranging from the nematocysts of the dinoflagellates to the complicated neuromotor systems of the trichonoymphid flagellates. Sex and sexual dimorphism, ranging from slightly different staining reactions between gametocytes to profound sexual dimorphism of gametes, have had their origin here. The Protozoa have provided the arena in which the primitive pageant of life made its first parade before it settled down into the more humdrum and less interesting mediocrity of metazoan and metaphytic conformity.

Let us then turn to the fundamental problem of the life cycle. Within the phylum of the Protozoa there have been evolved certain developmental processes which seem to have a rather precise correspondence with processes which constitute the fundamental parts of the life cycle of the Metazoa. These have attained their fullest development only in the highest representatives within the several classes of Protozoa, such as the ciliates, flagellates, Sarcodina and Sporozoa. They appear to have evolved independently in the several groups. Their origin thus seems to be polyphyletic. These points of agreement are:

1. The elaboration of the mechanism of heredity up to the point of nuclei with chromosomes whose individuality, continuity and diversification appear to be comparable with that attained in the metazoan nuclei.

2. The development of sex, of sexual reproduction—perhaps of the sex complex of chromosomes, and coincident with these the phenomena of gametogenesis and fertilization comparable in essentials of chromosome individuality and segregation with the conditions in the Metazoa.

3. The universal occurrence of the phenomenon of asexual reproduction, not to be confused with the attendant phenomenon of mitosis of unicellular organisms. Mitosis is important because of the unicellular state in some Protozoa.

4. The development of a multicellular stage following fertilization or following its possible equivalent; this multicellular stage I shall

designate as a somatella. In it there is generally no progress to the point of division of labor and differentiation of tissues, although the differentiation of sexual and somatic cells occurs in some instances, as in *Paramœcium* and *Volvox* and in the pansporoblast of the Sporozoa, and histological differentiation of the somatic cells is clearly arrived at also in the pansporoblast.

5. The occurrence of death as a biological phenomenon as normal to the Protozoa as it is to the Metazoa.

In addition to these unifying features which tend to bring into one biological scheme the Metazoa and the higher Protozoa, we have the outstanding fact to which biological thinking of the time has given too little attention; namely, that in many, possibly most, of the species of most of the Protozoa, and indeed in the still wider group of the Protista as well, sexual reproduction has never been found and probably does not occur in some species in which it has been reported. Nevertheless, there prevails among these primitive organisms the phenomenon of evolutionary divergence, or speciation, and the origin of specific distinctions. These distinctions seem to be indistinguishable in scope and kind from those of the Metazoa when tested by genetic studies, by morphological and cytological analyses, and by the more precise refinements of biochemical relations as revealed in serological reactions. Let us now turn to a fuller consideration of these points which I have enumerated as having been evolved in the group of Protozoa.

Prior to taking these up let us remind ourselves of the fundamentals of the life cycle of the living substance which constitutes so important a feature of this aggregate of matter and energy as over against that which constitutes the non-living world. The essential elements of such a cycle, be it in the plant or animal, in the Protozoa or the Metazoa, the Protophyta or the Metaphyta, appear to be the following:

We begin the cycle with the zygote, carrying two sets of ancestral genes contributed to the individual by the haploid gametes, thus establishing a diploid state in the individual. This diploid condition of the nucleus of the zygote is then transmitted to all nuclei of all cells of the subsequent subdivisions of the zygote until segregation takes place in gametogenesis.

The interaction between nuclei containing these genes and the cytoplasm in which they are found presumably controls by chemical action the subsequent processes of growth and differentiation and thus determines the volume and nature of new cytoplasm and its contents and the rate of its production. This control persists throughout the whole of the life of the zygote and of all of its subdivisions. We may designate the sum total of living substance thus controlled in all of the succession of functional individuals as the zygotic or Huxleyan individual.

The first step in the development of the zygote is cleavage and the formation of a multicellular complex which, in higher forms, becomes differentiated by histogenesis and organogenesis into complex and specialized organs of the individual.

The subdivision of the zygotic individual into varying numbers of functioning individuals by various processes of asexual reproduction is made possible by the persistence of undifferentiated tissues or by processes of dedifferentiation. The initial genetic equipment of the zygote thus continues its control throughout the life of all of these subdivisions resulting from asexual reproduction of different patterns. The genetic type of organization established by the fusion of the gametes maintains its integrity throughout this process, although the various bodies which may carry it yield to the assaults of the environment.

The universality of this phenomenon of asexual reproduction is one of the striking features of the living substance, especially in the Protozoa, where we see it manifested in binary and in multiple fission and sporulation of various types. We find it in the Metazoa in the budding processes of hydroids and medusæ, transverse segmentations of planaria and of the strobila of the tapeworm, in the various types of gemmules, statoblasts and brown bodies of Bryozoa, in the embryonic fission of midges and of the armadillo, and in identical twins in man. It may also appear in teratomata and embryomata of vertebrates and perhaps bears some relation to the potentialities of the living substance to afflict itself with malign neoplasms. The fact seems to be that

the living substance of the individual is constitutionally unable, even in its highest levels of evolution, to wholly shake off the deeply rooted tendency to reproduce others of its kind or other kinds, or to give rise to some other phase of a life cycle by some form of asexual reproduction. Broadly viewed, the whole evolutionary process in plants and animals appears to have progressed by the suppression of asexual reproduction and increasing emphasis on the differentiation of the body of the zygote as first produced.

It is therefore perhaps not without significance that the process of asexual reproduction is so deeply entrenched among the protists and antedates, in the process of evolution, the origin of sexual reproduction itself. In spite, however, of this tendency for the multiplication of functional units by the process of asexual reproduction, we find that the living substance sooner or later arrives at a stage both in ontogeny and in phylogeny in which gametogenesis ensues and by this method provision is made for the origin of new life cycles, starting with a variety of types limited only by the possible permutations in the ancestral genes and the viability and survival values of these combinations. With the accomplishment of gametogenesis the processes of senescence are hastened and the death of the individual or individuals ensues. We may summarize, then, the essential features of the life cycle as syngamy, or sexual reproduction; cleavage of the zygote; histogenesis and organogenesis and the division of labor; asexual reproduction resulting in the multiplication of functioning individuals; gametogenesis; senescence and death.

There has been a tendency in some quarters to set aside the Protozoa, as exempt from the program involved in this life cycle as manifested in the Metazoa and Metaphyta. Indeed, some have even denied the cellular character of the Protozoa while others have intimated that the phenomenon of heredity was of necessity of a different type in this primitive group and even that the Protozoa are immortal. In addition to these restrictions on the point of view there have arisen in the course of the investigations of the Protozoa certain interpretations of the developmental phenomena discovered therein which seem to militate against the possibility of the existence of one or other of these fundamental stages of the life cycle. Let us therefore turn to the Protozoa and consider in some detail in how far, in reality, they tend to conform to the common scheme of the life cycle which has been so widely adopted and prevails so universally in the Metazoa and the Metaphyta.

The first point to which our attention is turned is naturally the existence of the mechanism of heredity in the Protozoa. We are confronted at once by the statement that the Protozoa are not purely cellular; they are rather organisms. This question appears, however, to be purely a formal one and is met by the definition of a cell from the dynamic point of view, to wit: that a cell is not only a nucleus with a surrounding cytoplasm, but that it is also a chemical engine for the flux of matter and the flow of energy. Cell boundaries are not essentially a part of the definition of a cell. From the dynamic point of view the Protozoan is as surely a cell or a group of cells as is an egg or a blastula, or a man. The fact that it is also a complete organism within, it may be, the confines of one cell, merely complicates its structure by necessitating in many Protozoa the existence, within the cytoplasmic domain of a single nucleus, the presence of the organelles of the individual and the performance of the several different functions of life within the boundaries of the one domain. It is apparent to one who scans the widespread occurrence of multicellular states among the Protozoa that it is clearly a matter of entire indifference to the functional efficiency of the Protozoan as to how many cells there may be in its make-up. It is more a matter of importance that the quantity of the nuclear and cytoplasmic substances should be properly adjusted to each other and to the volume of matter and amount of energy in the process of transformation. There is such a suitable adjustment which Hertwig has long since emphasized which finds many illustrations in any comparative study of any considerable group of Protozoa. A huge radiolarian with the enormously complex skeletal structure composed of thousands of elements integrated in a common and complex pattern may have a single nucleus of huge dimensions with as many as 1,600 chromosomes. Two species of

flagellates living in the same environment in the digestive tract of a termite may have in one instance a single large nucleus with its attendant intricate neuromotor system of many complex elements, while the other of approximately the same size may have 2, 4, 8, or it may be 50 nuclei. But these will have in a general way a correspondingly small quantity of chromatin in each nucleus and the total in all of the nuclei will approximate in quantity that in the single nucleus of the accompanying species of like size.

Our conceptions of the nucleus in Protozoa have been thrown into confusion and to some extent therefore excluded from the category of metazoan and metaphytan nuclei by the accounts of protozoologists of the occurrence among Protozoa of certain cytological phenomena which appear to undermine and to render impossible our modern concepts of the mechanism of heredity in that they seem to invalidate the continuity and individuality of the chromosomes.

The complicating concepts are; namely, the occurrence of amitosis, of the formation of nuclei *de novo* from chromidia; chromidiogamy or the formation of gametes from chromidia; and of multiple nuclear division, in which a single nucleus parts at once into numerous nuclei. Added to this group of perplexing phenomena is the persistent proposal that Protozoa reproduce by the process of autogamy emanating from the Schaudinn-Hartmann school at Berlin and its followers.

Without attempting at this time to go into the cytological details necessary to refute any or all of these seemingly unusual and complicating cytological phenomena, I will pass them by with the statement that in the course of more than ten years of intensive work on the cytological processes of flagellates and rhizopods, I have been wholly unable to find any satisfactory cytological evidence to support any view that the nuclear phenomena of the Protozoa differ fundamentally from those of the Metazoa.

In the first place amitosis as described in the Protozoa is either a pathological or degenerative process, as it is in the Metazoa, or it is based on a partial account of the normal process of mitosis in which the nuclear membrane remains intact throughout the whole process, as it does in flagellates and rhizopods, and in its anaphases presents a superficial resemblance to pathological amitosis. The persistence of the nuclear membrane in no way interferes with the occurrence of chromosomes constant in number and kind. In other words, the doctrine of chromosome continuity, insofar as amitosis is concerned, is no more affected in the Protozoa than it is in the Metazoa.

We have had accounts of the *de novo* origin of nuclei and of chromidiogamy by an association of chromidia in the cytoplasm into new nuclei while at the same time the old nuclei disappear. These accounts of this process in *Arcella, Actinosphærium,* and in certain flagellates are, in our observation, the results of the failure to apprehend the fact that the process of metabolism in the protozoan individual brings about in the protozoan cell the formation of intracytoplasmic substances which, on the one hand, provide for the rapid multiplication of cells, as does the yolk of the egg after fertilization, and, on the other hand, obscure, by the very fact of their stainability, the actual process of mitosis in nuclei. The observer is led to give a false interpretation of degeneration to the condition in which the nucleus of the protozoan fades as a result of the process of metabolism, not unlike that in the growing egg during yolk formation. In this process it loses much of its stainability, appears to be degenerated and is hidden in the mass of stainable substance, the so-called chromidia, in the cytoplasm. It then undergoes rapidly a succession of cell divisions, during which period the chromidia are reduced in mass, the new nuclei show increased stainability, but the observer has mistakenly attributed their origin to the disappearing chromidia.

The *de novo* origin of nuclei in *Amœba proteus* described recently by Carter is, we believe, entirely of this nature. Similar accounts of *de novo* formation of nuclei and of chromidiogamy in *Arcella* appear to me to be of a similar nature, and it is possible there is also a confusion here by some investigators of moribund stages of individuals and of parasitized individuals. Some instances of the *de novo* origin of nuclei in flagellates appear to be instances of parasitism rather than *de novo* origin.

In like manner some at least of the so-called

cases of multiple nuclear division are to be attributed to a process of rapid mitosis rather than multiple, coincident fragmentation of a single nucleus. In any event, the cytological evidence upon which the processes of chromidial organization of nuclei, chromidiogamy and multiple nuclear division are based are undoubtedly wholly inadequate to establish the occurrence in the Protozoa of these biological processes so fundamentally unusual and so subversive to the more adequately founded concept of the mechanism of heredity. It appears that they should be dismissed entirely as wholly unproven in fact and be regarded as inadequate interpretations of other processes, normal, pathological or parasitic in nature.

The occurrence of autogamy in the Protozoa presents far less theoretical difficulties. Its incorporation in any system of interpretation of the operation of the mechanism of heredity involves no greater difficulties than does hermaphroditism and self-fertilization in the cestode or cleistogamy in the violet. The main difference lies in the fact that owing to the small size and limited number of cells in the protozoan cycle the uniting autogamous gametes are genetically nearer their common cellular ancestor than they are in the tapeworm or the violet. Some, however, of the processes of autogamy, as, for example, that of *Endamœba coli,* described by Schaudinn and by some other investigators in the parasitic Protozoa, rest upon misinterpretations of the process of cleavage in the encysted organism, and upon the mixture by investigators of the life cycles of several different parasites as parts of the cycle of one. We may conclude, then, that insofar as the fundamental nature of nucleus, chromosomes and mitosis is concerned, Protozoa conform in essential features to the nuclear mechanism of the Metazoa and that autogamy, if present, is not peculiar to Protozoa and offers no serious obstacle to the modern conception of the mechanism of heredity.

The existence of sexual phenomena in the Protozoa has been a matter of frequent record and of repeated observation in various types of Protozoa. It was the result not only of the brilliant series of interpretative papers by Schaudinn, foremost leader in modern protozoology, but also of those by his many followers. In a series of brilliantly conceived, rapidly developed and handsomely illustrated monographs, Schaudinn demonstrated the existence of sexual reproduction as a part of an elaborate life cycle in a series of Protozoa from rhizopods to the malarial parasite, thus giving rise to the general belief that sexual reproduction was probably universal in the Protozoa and that it was only a question of skillful interpretation and fortunately selected material for any investigator to be able to demonstrate its occurrence in any species of the group.

Some doubt has arisen as to the validity of some of Schaudinn's conclusions, and doubt also as to the accuracy of some of his observations. This has arisen in part from his well-known mistakes in his account of the life cycle of the trypanosomes in which he confused in one life cycle those of no less than three different organisms. The elaborate and critical work of Minchin and of others who have worked with trypanosomes has failed in the slightest to confirm Schaudinn's conception of the sexual reproduction of these organisms.

It would not be fitting for one to pass criticism on any of the other accounts which this investigator has given us unless one had himself painstakingly worked over similar material. I wish to take this occasion, however, to state that prolonged research with the protomonad, polymastigote, dinoflagellate and euglenoid orders of the Mastigophora and in the Rhizopoda during the past ten years by my collaborators, students and myself has thus far failed to give us the slightest critical evidence of the occurrence of sexual reproduction in any of these orders. It is possible to find in one's material and to picture, as Goldschmidt and others have done, a sequence of fixed and stained stages which will simulate, in the most striking degree, the successive steps in the process of sexual reproduction if one neglects chromosomes. But over against these facts one must place his observations that dividing flagellates may within the brief time of a single minute assume positions simulating in their space relations final stages of plasmotomy and to exhibit later the appearance of the initial stages of conjugation owing to the great facility with which the neuromotor organelles shift the positions of the parting sister cells. One should, therefore, utilize such material with

utmost caution. Throughout all of our work we have failed to find in the groups named the least evidence of gametogenesis and of syngamy based upon cytological evidence involving chromosome number and behavior. We are, therefore, highly skeptical of all accounts of sexual reproduction in the flagellates other than those in the Volvocidæ, where differentiated gametes, as in the case of *Volvox,* occur.

In the same way our recent investigations in the mitotic process occurring in the cysts of intestinal rhizopods leads us to reject entirely Schaudinn's account of sexual reproduction in this group, and has increased our skepticism in the account of its occurrence in the free-living rhizopods. It is a matter of prime consequence that protozoologists and others accept no account of sexual reproduction as adequately established which does not rest upon essential cytological features of gametogenesis and fertilization, and the clear cut, unquestionable establishment of the haploid and diploid sequence in these processes.

The seeming absence of sexual reproduction in the bacteria and in many of the protophytes combined with its seeming absence in the lower Protozoa does not militate against the fact of its establishment in the higher forms, but does bring us face to face with the fact that it is probably within the group of Protozoa and perhaps independently in its several orders that the phenomenon of sexual reproduction has had its evolutionary origin. Insofar as this fact bears upon our thesis that the life cycle of the Protozoa and the Metazoa are essentially similar we should have to admit that the similarity inheres only in the higher representatives of the several orders of the Protozoa, or at the most in the Sporozoa and Ciliata and in a number of species perhaps of the other orders.

This conclusion, if true, brings us to a consideration of the possibility that there may occur also in these primitive forms which now represent the earlier steps of the evolutionary process of the phenomenon of reproduction a periodic nuclear reorganization of the genes that is not primarily sexual. In its morphological features and in its relationship to the permutations of genes and to their origin in the life cycle such reorganization may play a part in the mechanism of heredity not unlike that accomplished by the phenomenon of sexual reproduction in the Metazoa. Whether there is such a nuclear phenomenon and the manner in which it operates are both matters upon which we have as yet little or no light. The phenomenon of endomixis appears to be somewhat more like that of parthenogenesis than a more primitive form of nuclear reorganization. In the absence of full knowledge of the behavior of chromosomes during endomixis in *Paramœcium* and other ciliates final judgment must be suspended as to the identity of endomixis and parthenogenesis.

It is an undeniable fact that in the Metazoa and Metaphyta the gametocytes go through a long period within which cell division is suspended and metabolic and histogenetic processes of considerable importance in the development of the egg and sperm proceed within and without the nucleus of the cell; thus, for example, the oocyte acquires its load of yolk and the spermatocyte prepares for the elaborate histogenesis of the resulting gamete. It is during this period of suspended mitotic activity that synapsis and cross-over which makes possible the segregation and new alignments of genes take place.

Let us also remind ourselves that following activation by fertilization, the egg, by reason of its food reserve in yolk, proceeds at once with a series of rapidly succeeding cell divisions. This phenomenon of cleavage is fundamentally and essentially similar in all Metazoa and Metaphyta. It is therefore unquestionably a fundamental phenomenon of the living substance, but it appears in these groups to be a consequence of the activation resulting from fertilization or its equivalent. This equivalent is found in some cases in the stimulation of ova to development by mechanical, chemical or physical external stimuli. These facts suffice to raise the query in our minds as to whether or not sexual reproduction is absolutely an essential feature even in those organisms in which the process of evolution proceeds by periodic reorganization of the genetic constitution by syngamy. Might it not be possible that there is a process in primitive organisms even more fundamental than sexual reproduction, in which the genes of the chromosomes

are subjected to periodic readjustments of an unknown kind during a period prior to the occurrence of renewed mitotic activity?

This inquiry directs our attention to the fact that in those Protozoa in which sexual reproduction does not occur, or at least has never been found, there occurs nevertheless the same type of periodic rest found in gametocytes followed by rapid cell division, resulting in the formation of a temporary somatella similar to that which is found following activation resulting from fertilization. I refer to the period of encystment so frequent in Protozoa which occurs in the presence of an abundance of food and appears to be primarily a cessation of motility, a period of elaboration of reserve food, and is followed by a period of rapid cell division.

Our attention has already been directed to the fact in the life cycle of human intestinal Protozoa. During our prolonged search among the encysted phases of these organisms for evidences of maturation and fertilization we have been wholly unable to detect the least traces of any critical evidence of the occurrence of either of these processes. We do find, however, that all of the six species known in man and some of the flagellates also found in human stools tend to encyst, and then to proceed with rapid cell division, building up a 4-, 8-, 16- or more-celled body within the cyst. Free living rhizopods and flagellates are known to exhibit the same phenomena.

The successive steps in this process are well illustrated in the species *Councilmania lafleuri,* the largest of the amœbæ of man. This amœba, which in its active stage feeds upon bacteria, red blood corpuscles and on the active and encysted stages of other protozoan parasites of man, prepares for encystment by the ejection of the contents of its food vacuoles and consequent reduction in volume. It then seals itself within an extraordinarily impervious membrane or cyst wall and immediately elaborates within the substance of its cytoplasm a centrally located and relatively very large glycogen vacuole. This substance exhibits the typical reactions to iodine and to Best's carmine which characterize the glycogen of mammalian cells. This glycogen vacuole may fill as much as one half or more of the volume of the cyst. It crowds the nucleus into the peripheral cytoplasm. Unfortunately, owing to lack of material, we have been unable to get at the nuclear modifications during this earliest phase by careful cytological studies. The stages available for examination have been mainly those subsequent to the formation of the glycogen. The nuclei during this period of greatest glycogen abundance are often very much enlarged and the chromatin which is usually gathered in the central karyosome may be spread out in expanded, greatly elaborated condition. The next step in the process is an elaboration within the outer cytoplasmic film and in immediate contiguity to the glycogen of numerous small chips or splinter-like chromatoidal bodies. As these increase in number the glycogen diminishes in volume until ultimately it entirely disappears. During the period of its decrease and the origin of these chromatoidal bodies, the nuclei begin their mitotic divisions, and generally proceed through the first and second of these divisions. When the glycogen has entirely disappeared, the chromatoidal bodies are generally found in a bundle lying near the center of the cyst, and reaching nearly from side to side. This cluster of bodies stains intensively with hæmatoxylin and may be the most prominent feature within the cytoplasm.

In the meantime the nuclei have passed through a third and fourth mitosis, resulting in 8 and 16 nuclei within the cytoplasm. At the termination of this process there then ensues a peculiar form of growth in which the 16-nucleated somatella which shows absolutely no trace of subdivisions proceeds to give rise to a series of budding amœbulæ which one after another are dropped off from the parent mass. This process bears a peculiar and significant relationship to the substance elaborated in the chromatoidal bundle and takes place with special reference to its location within the cyst.

In the first place a definite and minute pore is opened through the cyst wall directly opposite one end of the chromatoidal bundle. Prior to the opening of this pore there generally appears in the periphery of the cytoplasm a well-marked deeply staining strand of material in the form of a single arc or of a tripartite one. The substance of these structures is deeply chromophile and is even directly continuous with the end of the chromatoidal bundle

which appears to be reduced gradually in volume as the ridges are formed and the amœbulæ emerge. The chromophile substance from the ridges and from the end of the chromatoidal body seems to be drawn upon definitely by the cytoplasm emerging from the pore into the bud, so that the buds are noticeably more deeply stained than the cytoplasm of the parent somatella, and to correspond in stainability to the chromophile substance which antedates in its formation their emergence. Generally at some time before the budding process is completed the entire amount of chromophile material in the chromatoidal bodies entirely disappears.

The sequence of events within the cyst involving elaboration of glycogen and its disappearance, the formation of the chromatoidal substance and its relation to the growth processes, are suggestive of the sequence in the egg and the relationship of specific yolk substances to cleavage and differentiation in the metazoan egg.

It is obvious to one who studies the process of encystment so widely prevalent among the Protozoa that this feature of their life is not merely a device for survival during periods of drought and a means of protection which favors dispersal of the species into new localities. The process occurs in the presence of abundance of food and appears to be more clearly related to metabolism than to any protective necessity or impending danger of desiccation. It is certainly useful as a means for survival, but its origin and primary function appear to be fundamentally metabolic and related to growth. In view of this fact and of its intimate relationship to rapid mitosis and the formation of a multicellular body, one is led to infer that the period during which the glycogen is elaborated is one of profound cytological significance and one, perhaps, in which it may be possible for a nuclear reorganization to take place. Moreover, it may be that this is a reorganization of the genetic complex of its chromosomes. It is on this point precisely that we lack any cytological evidence at present. It is, however, to this period in the life cycle that I wish to direct the attention of protozoologists, geneticists and cytologists, with the hope that some one may find an organism in which this stage may be studied to advantage, because of the size of the nucleus, number of chromosomes, and ease of control of material.

Certain features of the protozoan nucleus appear to lend support to the possibility that there may be a more fundamental and primitive form of nuclear reorganization than that which sexual reproduction offers. These features are: first, the fact that in some flagellates only a relatively very small amount of the chromatin within the nucleus takes part in mitosis. In the second place, there appears in nuclei of the dinoflagellates to be a persistent organization of beaded chromosomes with subparallel or even spiral arrangements within the nucleus. This parallelism (though not synaptic) might offer a basis for cross-over, or its equivalent, during a period of syniezesis. Should such a phase in the cycle of the cell make possible such reorganization, we might find in them a mechanism for genetic modifications. The consequence of such permutations of the genetic substance might not be unlike those resulting from synapsis in sexual reproduction and thus provide for evolution in the absence of syngamy.

In this connection attention should be directed to the findings of Jameson upon the exact location in the life cycle of the period at which maturation occurs in the Sporozoa studied by him. He has found that reduction division follows immediately upon fertilization with the result that the haploid condition in these Protozoa persists throughout the natural period of growth and recurrent asexual reproductions which prevail during the life of the parasite within the host, while the diploid lasts but one cell generation. It thus appears that while in the Metazoa the haploid condition of the organism is limited to the second maturation division only of the spermatocytes and oocytes of the second order and thus to a very brief period in the total life cycle, in some Protozoa this diploid-haploid relationship may be reversed in relative duration.

In the light of the fact that many of the Protozoa appear to have no sexual reproduction, and yet nevertheless to have accomplished an evolutionary progress of no small magnitude, these observations of Jameson are significant. They lend weight to the possibility that sexual reproduction originates within the Protozoa, and, as in some of the cryptogams,

establishes a diploid condition controlling only a part and apparently only a very small part of the prolonged life cycle. It gives us occasion to consider whether or not sexual reproduction may not have been elaborated gradually and independently within different groups in the Protista, and subsequently in them and in higher forms of life the diploid state has extended its domain more and more throughout the life cycle of the organism. Indeed, the very fact that the Protozoa run with a six cylinder instead of a twelve cylinder engine, granting the universality of Jameson's observations for the sake of argument, may be the very reason why they have not been successful in building up a differentiated body. They run the multicellular part of their course with only a brief-lived and relatively inefficient somatella instead of a specialized soma.

It was stated in the introduction to this discussion that the Protozoa are multicellular as truly as the Metazoa. The difference between Protozoa and Metazoa lies not in the fact of occurrence, but in the degree to which multicellularity progresses. In the Protozoa the multicellular phase which results from cleavage is limited to few mitoses and small number of cells. In amœbæ, as far as we at present know, it does not get beyond a sixteen-celled stage. In most flagellates eight seems to be the stopping point. In *Paramœcium* likewise the eight-celled stage is the limit of the development of the somatella.

Furthermore, the length of life of the individual in the multicellular phase is generally a brief one, for example, the sixteen-cell stage of *Councilmania* proceeds rather quickly to asexual reproduction by budding, and in the most of the polymastigote flagellates the eight-celled somatella rather quickly disappears by successive plasmotomy into unicellular units. However, in both of these classes of Protozoa there are multicellular species which live for prolonged periods in the multicellular phase, as, for example, in the Foraminifera, in the pansporoblasts of the Sporozoa, in the colonial Volvocidæ, in some polymastigotes, and in not a few of the ciliates.

Some of the somatellas of the Protozoa proceed in the direction of histogenesis and the division of labor by the segregation of sexual and somatic cells, as, for example, in some of the Volvocidæ where the gametocytes form only a part of the body or in the pansporoblast of the sporozoans in which we have one or two sex cells enclosed within a body of four or more other cells and the body itself may be differentiated into cells of two kinds. In the case of the ciliates, we find, as in *Paramœcium,* the eight-cell stage of the somatella formed by cleavage differentiated into four somatic nuclei and four sexual nuclei—three of which degenerate, and the body thus formed proceeds by asexual reproduction to reduce the number of nuclei to the normal condition of a single trophic macronucleus and a single sexual micronucleus, a condition perpetuated by subsequent asexual binary fission.

It will perhaps facilitate our conception of the fundamental similarity of the life processes of the life cycle of the Protozoa and the Metazoa if we turn our attention to the familiar life cycle of the malarial parasite in which Schaudinn distinguished a cycle separated into two phases based upon the host in which the parasite lives. It is in this sequence that this cycle is treated in the text-books and charts which base their account upon his investigations. All start the life cycle with the invasion of a red blood corpuscle by the sporozoite introduced by the mosquito into the blood of man.

Looking at this problem purely as a biological rather than an anthropomorphic phenomenon one is forced naturally to begin the life cycle not from the point of importance to man, but at the most significant phase of the organism itself, namely, the zygote. This, the so-called ookinete, is formed in the stomach of the mosquito by the fusion of the slender flagella-like macrogamete or spermatozoan with the larger spheroidal, passive, immobile macrogamete or egg. It is in reality a fertilized egg which creeps out of the stomach of the mosquito, encysts in the wall of this organ, and undergoes rapid cell divisions giving rise to a multicellular plasmodium-like sporoblast, having hundreds and perhaps thousands of cells in a common protoplasmic body at first spheroidal in form and retained within the encapsuling membrane. There is no histogenesis in this body. Then follows an asexual reproduction in which the body falls apart into its constituent cells, comparable in kind

to the shaking apart of the blastomeres in the egg of *Amphioxus*. These separated blastomeres then differentiate in the unicellular sporozoite which may be transferred by the mosquito into the blood of man. Here they find a favorable field for their growth in or upon the red blood corpuscles and undergo a succession of mitoses giving rise to a small multicellular body which in turn undergoes asexual reproduction by simultaneous plasmotomy into its constituent cells, a process again similar to that of the breaking apart of the blastomeres of the egg.

This may be repeated again and again in the course of the cycle in the human host. There comes a time, however, in the life cycle in which certain of the merozoites instead of proceeding to the formation of new somatellas form instead gametocytes, and in the favoring environment of the mosquito's stomach proceed to the maturation of gametes. We have, then, in this protozoan, as in the case of the Metazoa and Metaphyta, the fundamental processes of fertilization, cleavage, asexual reproduction and gametogenesis with the gametocytes and gametes sexually differentiated. The parallelism is precise in every important respect except in the fact that histogenesis and organ differentiation do not appear even though the number of cells in the somatella on the wall of the mosquito's stomach may reach into the thousands.

It is also obvious that death is a normal part of this cycle as truly as it is in the case of a navel orange tree, the earthworm or man. It results, in the case of the navel orange tree, when any part of the original zygote disintegrates and is never fully accomplished until all its parts have disintegrated or have been transformed into gametes. The cycle of the individual extends from the zygote to the gametes. This individual is, of course, the Huxleyan individual and it dies when any of its parts which we may call functioning individuals die of disease or are destroyed by accident, or die of old age. But the Huxleyan individual does not entirely disappear until all of its parts reproduced asexually either perish singly or are transformed into gametes. Senescence and death in the navel orange tree are not unlike that in the malarial parasite. The original zygote which formed the navel orange is now dispersed in thousands and hundreds of thousands of navel orange trees throughout the orange orchards of the world. Some of these may produce new gametes, but in time they are destroyed by man and the environment, or grow old and perish, unless continued by asexual processes.

In the same way the malarial parasite dies with the formation of its gametes and is continued by asexual processes. In the case of *Paramœcium* the zygote undergoes cleavage, forms an eight-celled body which by asexual reproduction is reduced to the binucleate condition with the single trophic and a single sexual nucleus. This is continued indefinitely with the aid of endomixis, or at least the limits are not yet known to which lines of descent may progress by asexual reproduction.

There comes a time in the life of some of the asexually produced individuals in which the trophic nucleus or soma breaks down, its genetic control over the cytoplasm in which it has lived ceases. The sexual nucleus by the process of maturation takes over this body which in a dedifferentiated condition becomes that of the gamete, and ultimately that of the new zygote. We have here, then, in this and many other Protozoa, the rather exceptional phenomenon of the entire body of the parent controlled by the genetic complex of the macronucleus, growing old and its nucleus disintegrating and resorbed in the cytoplasm of the gametocyte and gamete. The gamete thus eats one of its parents. The only difference between this function and that of the hydroids or of a man lies in the fact that the amount of parental cytoplasm appropriated differs. *Paramœcium* takes it all, the human egg only a minute part. In both cases the ancestral genes which once controlled the parental cytoplasm are alike doomed to senescence and death, and a new régime is established in the new gamete and zygote.

We find also that there is a parallelism of deep significance between the relation of asexual reproduction in the Protozoa and in the Metazoa to the phenomenon of senescence and death. The tendency of asexual reproduction in all organisms is to prolong the chances of survival of the original zygotic complex in

one or another functional individual. In every case senescence follows and death is the price of sexual reproduction. The length of time during which asexual reproduction may prolong the existence of functional individuals carrying original zygotic constituents is a matter to be determined only by experiment and observation. It is not essentially different in the Protozoa and the Metazoa.

When we turn to those primitive forms of life in which sexual reproduction has not as yet made itself apparent, we are faced by the fact that it would appear at first sight that death can not possibly be a phenomenon where sexual reproduction is unknown. This is true, however, only if the original genetic complex remains unchanged. Should there, however, occur in the life cycle of the Protozoa and other primitive organisms, including the bacteria, a periodic and recurrent reorganization of the nuclear structure involving permutations in the genes, we will be forced to admit that every such organization carries with it inevitably the seeds of death of the previous individual. The genetic complex which existed prior to the reorganization vanishes when that reorganization ensues and a new individual in every sense of the word comes into control of the organization.

I have brought forward this concept of the normality of senescence and death among the most primitive organisms as one which may be helpful in directing discussion and research into the nature, structure and periodical changes in the mechanism of heredity and the mechanism of organismal control of these simplest forms of life. It may perhaps be helpful and serve to facilitate progress if we emphasize the similarities of organisms and seek to find the common processes underlying them all rather than to emphasize their differences and thus obscure our vision of the more fundamental problems of life.

C. A. Kofoid

## PRUNING THE ACADEMIC TREE[1]

There is little reason to offer excuse for discussing the method of presenting a scientific subject, if one but remembers that each science is rapidly expanding and as it does so the subject matter and pedagogical methods must be modified. We can not be content to teach as our forefathers taught even though they in their time were successful. Not so long ago there were naturalists who studied and taught all phases of science and the student obtained a certain advantage which is lost by our present system of special teachers. The intimate inter-relationships of the sciences are largely lost in the maze of special detail. The broad, inaccurate naturalists' teaching of earlier days had to give way to the closely analytic, specialized method of the last decade, but now the immense accumulation of data must be synthesized into the truly general, fundamental principles so as to free the students' time for further specialized study.

We all have been inclined, on the whole, to teach as though our students were going to be specialists in our particular subjects instead of realizing that this, in all likelihood, will be the one time in their course when they will come in contact with our subject. There is much that a specialist must know which but fogs the issue for one gaining general knowledge or training. We too often lose sight of the college ideal of education and attempt to turn out ambulating encyclopedias rather than individuals who are trained to organize and apply.

Each increase of knowledge has seemed to call for the addition of a requirement for graduation without greatly affecting the curricula already prescribed. The result packs the students' hours from entrance to graduation with one continuous procession of informational courses until, should the student by chance have a free hour in his program, he really feels guilty. Well might be inscribed over the gates of many of our colleges "Leave thought behind all ye who enter here" for small time is left for such intellectual processes.

We must cut the Gordian knot of required subjects for every hour of college life whenever possible in order that opportunity for individual selection may enter. We must recognize that in general elementary courses only the principles and not the details stick or are of ultimate value. Our work must be so planned that the student's life shall not be one

[1] Read before the North Dakota Academy of Science, May 5, 1922.

galaxy of memorizing of facts accepted on authority but rather that he may have opportunity to coordinate and prove his acquisitions and so become different from the trained ape from which so many to-day are fearful of having descended.

In all subjects there is something of recognized value to the well-trained mind but the time is past when we may know much about all things. We must present only the essentials of our subject to our students and let them judge whether they would go farther. Moreover, the increase in knowledge means that there are more fields for the student to investigate and as teachers we must eliminate many of the weeds in our intellectual gardens. Can this be done without making the student superficial? Our experience makes us feel certain that he will be better off under the proposed plan than under the cramming system.

It is becoming more and more evident that all living organisms, both plant and animal, are a unit in the principles which govern them. It is these fundamental ideas which are of importance to the great majority of students and it is these which they will carry away with them as the best heritage of an elementary biological course. Why then burden them with mastering a mass of detail, so soon to be forgotten?

In biology it has been the custom to start with the Amœba and end with man, hitting as many forms in between as time and the budget would permit. In one institution a student was heard to remark that specimens flowed past at such a rate that if he chanced to look around he lost a view of several. There are few teachers to-day who can make such a "type" course interesting and the student loses the great basic principle of life in viewing its numerous manifestations. It is far better to demonstrate the principles thoroughly with a few well chosen forms. We want the students to have at the end of their course a realization that metabolism, irritability, movement, reproduction and growth are the principles or characteristics of living matter. If this can be done and the student then brought to a realization of the organic variations which successfully carry on these functions, he has acquired about all of biology that will be useful to him. If his first experiences hold his attention then he may go on into the more advanced and specialized courses. We will in this method sacrifice only the time-honored, traditional and more or less useless detail. The fundamentals will stand out sharply in relief and in that form will not readily slip away.

Thus instead of two elementary courses, one in botany and one in zoology, a single course in the fundamental principles of biology may be developed with the cooperation of both departments. The student can not be a botanist or a zoologist from such a course, but neither will he be from an elementary course in either. He may, on the other hand, get a more comprehensive view of life and its essential applications to his than from a more specialized course in botany or zoology. Thus the general student is better served, but what shall we say of those who need special phases of either subject? They are better served in advanced courses where smaller numbers of students make for greater opportunity.

This plan has been put into operation at the North Dakota Agricultural College with what appear, from first returns, to be satisfactory results. Instead of six terms of elementary work in botany and zoology, two in the principles of biology are given. These are followed for special groups of students by special courses especially fitting their needs. Thus those who specialize in the agronomic phases of agriculture have three terms of advanced botany in place of one or possibly two heretofore. Likewise the animal husbandry students are especially served in the advanced courses in zoology. A unique feature of this plan is the complete cooperation of two departments in outlining and conducting the introductory course, not breaking the continuity of the subject matter into separate terms of botanical and zoological work. Thus unnecessary duplication is eliminated and every subject of discussion is strengthened by the presentation from both points of view.

The educational ideal would be to offer the student an opportunity of getting a rapid survey of all branches of learning that he might better be able to choose his field of interest. This not being entirely possible it is desirable that our general courses be pared to

the core and we may rest assured that the subjects will gain rather than lose in their value to the students.

Students have justly complained that so many required subjects fill the curricula that they can not elect in their special field of interest during their last two years. At Barnard College the students have petitioned for such general survey courses in many subjects as that outlined here for biology.

Most of our academic trees carry much dead wood. Can not other collegiate subjects profitably eliminate much detail which now seems sacred in the elementary course and thus open the way for more intensive study in the later years of the students' curriculum?

E. S. Reynolds
R. T. Hance
North Dakota Agricultural College

## COOPERATION OF THE GOVERNMENT IN SCIENTIFIC WORK

In view of the growing interest in cooperation as a means of advancing scientific work for the public benefit, the National Research Council in 1921 appointed a committee to study the nature and extent of cooperative scientific work carried on by the federal government and outside agencies as well as the principles which should guide in such work. This committee consisted of E. W. Allen, chief, office of experiment stations, United State Department of agriculture, chairman; Edwin F. Gay, president, New York Evening Post, Inc.; M. W. Glover, bureau of chemistry, United States department of agriculture; N. C. Grover, geological survey, United States Department of the Interior; Vernon Kellogg, permanent secretary, National Research Council; and E. B. Mathews, state geologist for Maryland and professor of geology, Johns Hopkins University.

The committee's report, which has just been made public by the council, shows a great diversity as to types of work, agencies cooperating, nature of cooperation, terms of agreement and extent of participation of the parties to it. The inquiry revealed 553 separate cooperative projects, involving more than 1,100 cooperative undertakings, since many of the projects involve the work of several cooperators. Of the 553 separate projects, 360, or nearly two thirds, fall under the head of research, the acquisition of new knowledge by the method of systematic scientific investigation; others deal with routine testing and technical service; gathering of statistics; enforcement of regulatory laws or measures; and the like.

The federal agencies engaged in the cooperative work included some 23 bureaus and independent establishments of the government, and the outside cooperating agencies included various branches of the state governments, municipalities, chambers of commerce, state and endowed universities, agricultural colleges and experiment stations, botanical gardens, and similar institutions, as well as associations and societies of various kinds and numerous industrial concerns and private individuals.

The forms of agreement or understanding entered into between the cooperating parties are very diverse. As a rule, however, they are quite definite, and in general, "convey the impression of having been developed in the spirit of cooperation and with a view to avoiding misunderstanding."

The combined cost to federal and outside cooperators of the definitely organized scientific work in which the government is concerned aggregated, as far as the available data show, more than $41,000,000 for the year under consideration. Of this, over $14,000,000 came from the federal government and nearly $27,000,000 from outside agencies. If the assistance other than money is included, it appears that the outside cooperating agencies are putting in fully two dollars for every one supplied by the government. As the report states, however, "the influence of the federal government in stimulating new movements for the application of science can rarely be measured by the amount of funds it has contributed. It has served to nationalize many types of effort important to the intelligent advancement of the country, and has greatly hastened the development of such measures."

Of the federal agencies concerned, the United States Department of Agriculture has the largest number and the widest range of coopera-

tive undertakings. The report shows that the cooperative work covers the entire country and includes broadly "the study of the principles of agricultural science, the determination of agricultural resources and special adaptations, the discovery and introduction of improved or better-suited methods, the establishment of new crops, the improvement of plants and animals, the marketing of products, and the safeguarding of agriculture from a long list of enemies."

The cooperative enterprises to which the department of agriculture is a party, excluding cooperative extension and experiment station work, road building and management of forest reserves, involved in 1921 a total expenditure of nearly $15,000,000, of which the department supplied $5,844,307.

Leading purposes of the central government in fostering cooperation have been to provide for the more adequate scientific investigation of matters of general interest from a national or regional standpoint and to promote nationwide movements of various kinds. As pointed out in the report, "the scientific work which the government, the states and local institutions are called upon to perform is so vast and so varied that it is beyond the ability of a local or national agency to accomplish, working alone. Much of it is regional or national in importance or is for the benefit of science as a whole. To prevent its being fragmentary and disconnected, systematized effort is manifestly important."

The survey shows that cooperative scientific work is on a large scale and steadily increasing. In fact it is evident, as the report states, that such cooperation "has become a recognized principle of government." The number and range of the cooperative projects make it clear that "the states have no hesitation in joining hands with the federal government in carrying on research and development work of interest to them. . . . And that there is a manifest tendency on the part of the states to seek the aid of the federal government in measures of general or regional interest, and to link their efforts with those of the central agency, is shown by the fact that such proposals frequently originate locally."

## SCIENTIFIC EVENTS

### SCIENTIFIC RESEARCH IN AUSTRIA IN 1922[1]

IN a short report to the government, which demonstrated the meagerness of the regular appropriations to the scientific research institutes, Professors Becke and Rademacher asked for larger appropriations, and enumerated the most important investigations conducted last year in this country. Apart from the publications dealing with the geographic and ethnographic researches in the Balkans in 1915-1918, when our armies occupied these countries, the results of which were made known in 1922, one of the most important papers was that by Dr. Schedler, who made geomagnetic surveys in thirty different places and found marked differences and changes from the values heretofore accepted.

The Vienna Radium Institute, a private concern, has done excellent work in the investigation of radioactive substances. It has been shown that the age of certain mineral deposits can be estimated according to the proportion of transformation or decay of the radioactive substances contained in them. While the uranium-pitchblende of Bohemia is about 200 million years old, in Norway there are minerals at least twice as old, and in Ceylon the layers of thorianite have been found to be at least 500 million years old.

A tremendous amount of work is still going on in the biologic institute (Vienna). Here the problems of transplantation have attracted the attention of a number of gifted investigators. The pupils of Przibram study especially the physiology of transplanted eyes, hearts and legs. Koppanyi has succeeded in transplanting eyes in rats, and these eyes seem to be functioning. At a recent meeting of the Vienna Ophthalmologic Society, his experiments were vehemently attacked by the oculists, but just as vehemently defended by the physiologists. Dr. Weiss transplanted entire limbs in amphibia, exchanging, for instance, arms and legs, and demonstrated that these transplanted limbs functioned normally after

[1] From the *Journal* of the American Medical Association.

a few days. In a group of these animals, he could even transplant whole hearts into the peritoneal cavity. These transplanted hearts obtained an organic union with the new host, the animal thus having two hearts.

In the chemical laboratories of the university, important researches on the catalytic effects of copper and of the methyl-groups of methylated benezene compounds are in progress. In the physical institute, studies on colors and their differentiation are conducted by Dr. Duschek-Frankfurt. A prehistoric cave, discovered in the Styrian Alps near Mixnitz, gave opportunity for the study of animals and plants of diluvial times, while the results of botanic researches in the Far East and in the African Sudan, begun by Austrians before the war, have been published recently.

## PHYSICS IN INDUSTRY AT THE WEMBLEY LABORATORIES[1]

THE General Electric Company, Ltd., is now a very large organization, which employs some twenty thousand workers. It has engineering works at Birmingham, where it manufactures all kinds of electrical machines. At Stoke, near Coventry, telephones are manufactured. At the Osram lamp works at Hammersmith, lamps and valves of all kinds are made. At Erith, the company took over a few years ago the works of Messrs. Fraser and Chalmers, which manufacture steam turbines and mining plants. At Southampton, electric cables of all kinds are manufactured, and the company has glass works at Lemington-on-Tyne. Mainly on the initiative of Mr. Hugo Hirst, the managing director, it was decided some six years ago to establish a central laboratory to carry out the scientific and industrial researches which are essential for the progress of industry. Mr. Clifford Paterson, who was then the head of the electro-technical department of the National Physical Laboratory, was appointed superintendent, and he is now helped by a staff of physicists and engineers, many of whom have world-wide reputations.

The opening of the research laboratories on February 27 was a very interesting function. Lord Robert Cecil, speaking at the opening ceremony, said that the immediate task of the country is to repair the waste of the war. To do this the first and most essential requirement is to use every endeavor to increase the output of human energy and skill. This can only be done in two ways, namely, by reducing expenditure and by increasing the efficiency of production. Research, by making every man's skill go further, adds to the world's wealth. Science has no territorial boundaries. By promoting research the relations between this country and the world are improved. Sir J. J. Thomson, who also spoke, pointed out that it is absolutely necessary that a research laboratory should have a highly efficient staff. The capacity for the highest kind of research is rare. Training may increase the efficiency of a researcher, but it can not put insight and originality into him. It is also certain that no research laboratory can guarantee delivery. The output of such a laboratory is always highly irregular and spasmodic. Sir Joseph Thomson also dwelt on the importance of cultivating the thinking powers of the community to the utmost.

The research laboratories are situated near Wembley and have a total floor area of 80,000 square feet, but they have ample room for expansion. The building has a north-light roof and nearly all of it is only one story in height.

[1] From an article in *Nature*.

## THE UNIVERSITY OF MICHIGAN BIOLOGICAL STATION

THE fifteenth session of the University of Michigan Biological Station will be held on the shores of Douglas Lake, Cheboygan County, Michigan, during the eight-week period from July 2 to August 24. This station offers unique advantages for the study of a fauna and flora marked by the inclusion of the northern boreal forms and many of the forms characteristic of the region further south, the area being in the transition zone between the northern-eastern coniferous forest area and the central deciduous forest. The summer climate of this region is ideal for outdoor work of all kinds.

The station is conducted as a camp, with log and frame buildings for laboratories and small frame houses and tents for living quarters. A mess, operated on the cooperative plan, furnishes table board for the members of the station. Located six miles from the

nearest village and three miles from the nearest farmhouse, the station furnishes a fine experiment in community life. This isolation makes for a minimum of distraction and for concentration of interest upon biological work.

The class period lasts through the working day, thus permitting all-day field trips. Certain classes make two or three day excursions to the sand dunes along the shore of Lake Michigan. The curriculum for this session has been enriched by the addition of new courses and the expansion of some of the old. Courses will be given in ichthyology, limnology, entomology, ornithology (two courses), herpetology and mammalogy, cryptogamic botany, taxonomy of the bryophytes, systematic botany (two courses), ecology and plant anatomy. Students undertaking research under direction will find a wide variety of fields from which to select subjects for investigation. The more than one hundred and twenty-five published papers bearing on the biota of the region attest the interest of former members of the station and the encouragement given research by those in charge.

The teaching staff will include Professor P. S. Welch and Dr. F. N. Blanchard, of the University of Michigan; Professor H. B. Hungerford, of the University of Kansas, and Mr. Francis Harper, of Cornell University, in zoology; Professor J. H. Ehlers, of the University of Michigan; Professor F. C. Gates, of the Kansas State Agricultural College; Professor G. E. Nichols, of Yale University, and Dr. H. A. Gleason, of the New York Botanical Gardens, in botany. Mrs. Margaret T. Gates will serve as dean of women, and Dr. Warren E. Forsythe, of the University Health Service, will be the physician to the biological station. All inquiries should be addressed to the undersigned.

GEORGE R. LA RUE,
*Director*

ANN ARBOR, MICHIGAN

## RUSSIAN EXILED INTELLECTUALS IN BERLIN

THOSE who responded to an appeal made by me through SCIENCE some time ago for small sums to make up a total of one thousand dollars to be used for the special relief of approximately one hundred Russian university professors and other intellectuals exiled from Russia by the soviet government, and now trying to keep alive in Berlin, where local charity is feeding and lodging them, but is unable to do more, will be interested in news of what is being done with the money put into my hands.

The total amounted to a little more than twelve hundred dollars. This was sent to Berlin to be carefully distributed by a special small Russian committee, overseen by Captain Gardner Richardson, of the American Relief Administration, and Mr. Paul B. Anderson, of the Y. M. C. A. The committee is composed of Professors N. A. Berdiaeff, Bogilepoff and Iassinsky and Mme. E. L. Kousskoff. The first action of the committee was to express its gratitude to the individual donors of the money and to the editor of SCIENCE, and to ask me to make this gratitude known to these persons. This is done herewith.

The second action was to begin at once a careful distribution of the money. I have a full list of this distribution as so far made. It is a pathetic document. I can use space to note but two or three items:

To E. L. Soubasheff, former rector of the Technological University of Tomsk, $15.

To A. L. Baikoff, professor in the University of Moscow, with family, $30.

To I. A. Iljin, professor of Moscow University, with family, $30.

To V. D. Golovatcheff and I. L. Tchesliar, members of student organizations in Moscow, sent out with professors, each $10.

And so on. I hope that each donor will realize how much his money is doing. Ten dollars make the difference between suicide and keeping alive for some of these people.

VERNON KELLOGG

NATIONAL RESEARCH COUNCIL

## SCIENTIFIC NOTES AND NEWS

SIR JOSEPH THOMSON gave an address at Yale University on April 4 in connection with the dedication of the Sterling Chemistry Laboratory and the meeting of the American Chemical Society. His subject was "The unity of physics and chemistry." Next week he delivers a course of lectures at the Franklin Institute, Philadelphia.

PROFESSOR ALBERT EINSTEIN, of the University of Berlin, delivered three lectures in French at Madrid during the first week in March. The King presided at a sitting of the Academy of Science at which Professor Einstein was elected a member.

THE Willard Gibbs Medal of the Chicago section of the American Chemical Society has been awarded to Professor Julius Stieglitz, of the University of Chicago, for his researches in organic chemistry. The medal will be presented in May.

THE University of Dublin on March 12 conferred the honorary degree of M.D. upon Dr. William James Mayo, of Rochester, Minnesota.

DR. STOCKIS, professor in the University of Liége, has been elected president of the Belgian Federation of Scientific Societies.

PROFESSOR ANDRÉ MAYER has been elected president of the French Society of Biological Chemistry.

LEONARD SUMNER was elected president of the British Institute of Metals at the annual meeting on March 7.

THE Joseph A. Holmes Safety Association of Washington, D. C., has awarded the gold medal of the society to Dr. Andrew W. Springs, Dewmaine, for his heroic work in the Royalton explosion of October, 1914.

THE Adams prize for an essay on "The theory of the tides" has been awarded by the University of Cambridge to Mr. J. Proudman, Trinity College, director of the Liverpool University Tidal Institute.

PROFESSOR GEORGE E. BEGGS, of the civil engineering department of Princeton University, has been awarded the Wason Medal for 1922 by the American Concrete Institute for the most meritorious paper before the institute. The subject of this paper, which was delivered a year ago, was "The mechanical solution of indeterminate structures."

AT a meeting of the Academy of Natural Sciences of Philadelphia held on March 20, the following were elected correspondents: Charles W. Andrews, Ignacio Bolivar y Urrutia, Marcellin Boule, Friedrick Czapek, Herman L. Fairchild, Stephen A. Forbes, Gia Battista Grassi, Louis R. Jones, Vernon L. Kellogg, Charles A. Kofoid, James Playfair McMurrich, George P. Merrill, James G. Needham, Charles C. Nutting, W. J. V. Osterhout, Reginald C. Punnett.

As a token of admiration and gratitude to Dr. James Perrin Smith, professor of paleontology at Stanford University, about one hundred of his students and former students, many of them now eminent in geology and engineering, recently presented him with $10,000 at a campfire supper in the court of the geology buildings on the Stanford campus. Among those who spoke were R. P. McLaughlin, of San Francisco, former head of the petroleum department of the state and now a consulting geologist; E. B. Kimball, a mining engineer associated with W. P. Hammond in San Francisco; R. S. Holway, professor of physical geography in the University of California; A. M. Strong, consulting engineer in Los Angeles; Ralph Arnold, consulting geologist and petroleum expert in Los Angeles; T. J. Hoover, head of the department of mining at Stanford University, and R. B. Moran, geologist and engineer of Los Angeles.

DR. ELIHU THOMSON, of the General Electric Company, Lynn Massachusetts, was tendered a dinner in the Boston City Club on March 29 by more than seventy-five friends and associates in the General Electric Company, and from Harvard University and the Massachusetts Institute of Technology, on the occasion of his seventieth birthday anniversary. He was presented with a silver loving cup, the presentation being made by Walter C. Fish, formerly manager of the Lynn works, who served as toastmaster. There were addresses by Professor A. E. Kennelly, of Harvard University; Professor Dugald C. Jackson, of the Massachusetts Institute of Technology; Professor Comfort Avery Adams, of Harvard University; George E. Emmons, of Schenectady, vice-president of the General Electric Company; J. R. Lovejoy, of New York City, also a vice-president of the company; Herman Lemp, of Erie, Pennsylvania, and F. P. Cox, of Lynn, Massachusetts.

DR. WALTER ROSENHAIN, chief of the metal-

lurgical department of the National Physical Laboratory, Teddington, England, who has been lecturing in the United States, was on March 31 tendered a banquet at the Cosmos Club under the auspices of the Washington Academy of Sciences. Following the dinner, he spoke on "The structure and constitution of alloys."

THE report of the findings of the board of visitors to the Bureau of Standards has been issued. The board of visitors is composed of John R. Freeman, former president of the American Society of Civil Engineers; Ambrose Swazey, former president of the American Society of Mechanical Engineers; F. W. McNair, president of the Michigan School of Mines; S. W. Stratton, president of the Massachusetts Institute of Technology, and Wilder D. Bancroft, professor of chemistry at Cornell University.

WILLIAM R. HART, since 1907 head of the department of agricultural education at the Massachusetts Agricultural College, retired under the law of the state of Massachusetts on March 31, on his seventieth birthday.

DR. F. C. WEBER, since 1907 chemist in charge of the animal physiological laboratory of the Bureau of Chemistry, has accepted a position with the Fleischmann Laboratories, New York.

PROFESSOR J. B. HILL has resigned his position as professor of electrical engineering in the Iowa State University to enter the public utility field at Lincoln, Nebraska. He will be general manager and consulting engineer of the Lincoln Gas and Electric Company.

DR. WILLIAM N. BERG has resigned his position as pathological chemist in the pathological division, Bureau of Animal Industry. He is now engaged in the manufacture of biological products at the Berg Biological Laboratory, Brooklyn, New York.

DR. W. A. MURRILL left on March 3 for a collecting expedition in Florida. His trip will extend down the west coast from Crystal River to the Keys and back on the east coast as far as Daytona. Chief attention will be given to the collection of fungi.

THE twenty-eighth annual meeting of the Michigan Academy of Sciences, Arts and Letters opened in Ann Arbor on March 28. Professor William B. Scott addressed the academy on March 29 on "Evidences of evolution."

DR. OTTO MEYERHOF, professor of physiology at the University of Kiel, will deliver the eleventh Harvey Society lecture at the New York Academy of Medicine on Saturday evening, April 14. His subject will be "Autooxydation processes in the cell."

DR. LOUIS A. BAUER, director of the Department of Terrestrial Magnetism, gave on March 31 an illustrated talk at the General Electric Company, Schenectady, N. Y., on "The present status of our knowledge regarding the constitution and causes of the earth's magnetic field." He also gave a talk on "The earth's magnetism" at the General Electric Company, West Lynn, Massachusetts, on March 30.

PROFESSOR RICHARD GOLDSCHMIDT, of the Kaiser Wilhelm Institut für Biologie, Berlin, recently invited to deliver a series of lectures in England on his work concerning the sex problem, has lectured before the Genetical Society and at the Universities of Oxford, Cambridge and Liverpool.

PROFESSOR JOSEPH S. AMES, of the Johns Hopkins University, will give the Wilbur Wright memorial lecture of the Royal Aeronautical Society in London on May 31.

PROFESSOR H. A. LORENTZ, of Haarlem University, will on May 15 deliver the Rede lecture at the University of Cambridge on "Maxwell's electromagnetic theory."

SIR JAMES DEWAR, the eminent British chemist, died on March 27 in his eighty-first year.

DR. NORMAN DALTON, formerly senior physician to King's College Hospital, professor of pathological anatomy in King's College, and lecturer on medicine at the medical school, died on March 9, aged sixty-five years.

PROFESSOR IGNAZ VOGEL, director of the bacteriological department of the Agricultural Institute of the University of Leipzig, has died at the age of fifty-two years.

PROFESSOR PAUL JACOBSON, general secretary of the German Chemical Society, died in Berlin on January 26.

## UNIVERSITY AND EDUCATIONAL NOTES

RENSSELAER POLYTECHNIC INSTITUTE receives $40,000, Princeton University $50,000, and Lafayette College $50,000 by the will of Calvin Pardee.

THE building of metallurgy at the Michigan College of Mines, Houghton, Michigan, was destroyed by fire on March 15, with loss estimated between $250,000 and $275,000. Valuable records were lost, including those of the United States Bureau of Mines, occupying offices in the building.

COURSES constituting the first two years of the four-year course in medicine at Rush Medical College are given at the University of Chicago and include work in zoology, anatomy, physiology, physiological chemistry and pharmacology, pathology, hygiene and bacteriology. For the summer quarter the regular faculty in these courses will be supplemented by men from other institutions, including Wade Wright Oliver, professor of bacteriology, Long Island College Hospital; William Barnard Sharp, professor of preventive medicine, University of Texas Medical School; William Alfred Starin, professor of bacteriology, Ohio State University, and Andrew Conway Ivy, assistant professor of physiology, Loyola University.

EUGENE J. RIGHTS, a graduate of Lehigh University who has been engaged in bridge construction, has been appointed professor of civil engineering at the University of Porto Rico.

DR. L. PLASENCIA has been appointed professor of biological chemistry in the University of Havana.

MR. M. B. R. SWANN has been elected to a fellowship at Gonville and Caius College, Cambridge, and appointed a lecturer in pathology.

## DISCUSSION AND CORRESPONDENCE

### WEATHERWAX ON MAIZE ENDOSPERM[1]

DR. WEATHERWAX has recently contributed a very interesting paper to *Genetics* entitled "A rare carbohydrate in waxy maize." It is written with that inimitable blending of the didactic and the dogmatic which approaches true perfection in all of the author's work.

Two ingenious ideas led to this paper. Presumably there would be no claim that these ideas are absolutely original; but at least they have not been utilized before to the full extent of their possibilities. The investigation consists of observing the color reaction when iodine dissolved in aqueous potassium iodide is applied to the endosperm of a variety of maize. In itself this is not new. It has been done frequently by various botanists, and even by geneticists. The novel idea, the idea which might be termed ingenious without misrepresentation, is to make a complete and well-rounded investigation out of this one experiment. The second adroit idea is to omit all the vulgar details of this test in order that there may be no hindrance, obstruction or inhibition which might prevent the fullest freedom in drawing the most general conclusions. This again has its prototype. Sir Isaac Newton is said to have made a single experiment with falling bodies, utilizing the apple as material; yet the plan, the scope, and the mode of carrying on his observation are unmentioned in the two great works to which it gave rise. Thus it will be seen that the author deserves high credit for eliminating all that is extraneous and leaving his work characterized by utmost simplicity.

But it is in the comments, conclusions and generalizations regarding genetics that Dr. Weatherwax's originality is most striking; though it must be confessed they have a generic resemblance to those of other morphologists who have invaded the field. His first conclusion is that since waxy maize gives a red color with the iodine solution, its endosperm is composed wholly of erythro-dextrin, a rare carbohydrate having the unique property of producing this color reaction. Generously, though perhaps unnecessarily, he cites as corroborating authority for these facts a paper by Meyer written in 1886. Doubtless because chemical literature is notoriously erroneous, he has been able to dispense with the relatively large literature on the subject, much of which has been brought together by Abder-

[1] Weatherwax, Paul. A rare carbohydrate in waxy maize. *Genetics*, 7, 568-572, 1923.

halden in the *Biochemisches Handlexicon.* It might be of a little historical interest, however, to note that Haas and Hill (*Chem. Plant Prod.*, p. 107), after commenting on the ill-defined mixture of substances known collectively as dextrins, quote Ost as disputing the existence of erythro-dextrin as a chemical entity because he has obtained the red reaction with iodine on an artificial mixture of achroo-dextrin and starch.

Our author is at his best, however, in scourging the careless, inefficient genetic work of the past. He says in one place: "Geneticists of the past quarter of a century have found in hybrids between sweet and starchy varieties of maize, material readily utilizable for illustrating Mendelian ratios. But in the majority of the experiments reported, the 3 to 1 ratio expected in the conventional $F_2$ generation (of endosperms) has been complicated by the occurrence of grains intermediate between sweet and starchy." In determining to use the word "majority," the hundreds of crosses reported by Emerson, East, Merle Coulter and others, where only 1 or 2 per cent. of the matings were thus complicated, were omitted. The reasons for the omission will probably be given in a later paper.

Geneticists will also await expectantly an explanation of the statement that "the usual recourse has been the citation of the possibility of reclassification, based upon the degree of expression of the characters concerned, or an interpretation based upon various observed or assumed conditions." Until our attention was drawn to the case, the method used by geneticists of classifying doubtful individuals by the common practice of growing them and finding out how they breed had seemed just and proper.

Again, Dr. Weatherwax shows his clairvoyance in regard to genetic work by pointing out how much fruitless investigation of the maize endosperm could have been avoided by paying attention to its chemical and physical nature. If this had been done, he says, the divergent views of Dr. Harper on the one hand, and geneticists on the other, would be brought closer together, and Dr. Jones's investigation of the heredity of "pseudo-starchy" endosperm might have had more conclusive results. And with telling effect, he deals a final blow with an apt and striking metaphor. He says: "The visual method of discriminating between endosperm textures by observing the outside of the grain is as crude as a color-blind man's attempt to describe the rainbow."

Numerous other genetic hypotheses, which the author did not see fit to mention, fall before this type of criticism. Dr. Morgan has been crossing and recrossing *Drosophila melanogaster* for the past fifteen years, and has built up a seemingly consistent, orderly and logical scheme of inheritance upon the results. But many persons have felt that this consistency, this orderliness, this apparent logic was perhaps a mere phantasy or mirage which would disappear when a particular dispelling agent was discovered. Is it not probable that Dr. Morgan's ignorance of the chemical constitution of the characters with which he is dealing has led him into a maze from which he can never extricate himself? Furthermore, it is unquestionably true that in Dr. Jones's researches on the heredity of "pseudo-starchy" endosperm, he was unable to state the exact chemical constitution of the characters with which he dealt. There seems no escape from the conclusion that the deficiency vitiates his work.

Geneticists were not interested in whether there was a difference of opinion between Jones and Harper. They were interested in the facts. And these facts seemed to prove that "pseudo-starchy" had a different heredity from "true" starchy and from "sweet" endosperm. They accepted his work as an advance in knowledge on this account, even though a simple interpretation of the heredity mechanism was impossible. How crude and unsophisticated such a view now appears!

The reviewer does not wish to put an interpretation on Dr. Weatherwax's statements which he himself did not intend, but there appears to be a mute accusation between the lines of his metaphor concerning the color-blind man. Do geneticists endeavor to camouflage their deficiencies to the public by appearing to be doing the things which Dr. Weatherwax says they do not do? We have been in several genetic laboratories where maize endosperm was being investigated. The workers were cutting sections said to be for microscopical study. They were treating their material with various

chemicals supposedly to try to gain an insight into the chemical composition of the material. Perhaps their silence on this matter, as contrasted with their relative multiloquence on the pedigree culture data, is indicative of a capacity to judge the comparative importance of the facts, rather than a crafty masking of inefficiency.

E. M. EAST

## NEW OCCURRENCE OF THE BELT TERRANE IN MONTANA

No occurrence of the Belt Terrane in central Montana has been reported east of the Little Belt Mountains which were mapped in 1892-97 by Weed and Pirsson in Folio 56 of the United States Geological Survey.

Recently the writer has discovered over 100 feet of the top of the Belt Terrane in the Big Snowy Mountains. These mountains are about thirty miles long and are located east of the Little Belts, from which they are separated by a pass several miles broad called Judith Gap. The Big Snowies are the result of an anticlinal fold and contain no igneous rock, thus differing from all the rest of the outlying ranges in Montana. The summit of the uplift was reached at Half Moon Pass in the eastern part of the range, and the exposure of the Belt Terrane is on the south side of this pass in the canyon of Swimming Woman Creek.

The exposure of the Belt consists of dark gray, reddish and greenish shale or fissile slate. The rock is hard and highly fractured. Veinlets of iron stained quartz and calcite containing small amounts of gold and copper fill some of the fractures and joints in the strata. The Belt Terrane is exposed over an area of possibly two or three hundred acres. The Belt is overlain by more than 1,000 feet of Cambrian strata at the base of which is a quartzitic basal conglomerate. The walls of Swimming Woman Canyon are composed of the Cambrian and the hard Devonian and Mississippian limestones. There is an angular unconformity of a few degrees between the basal Cambrian quartzite and the Belt Terrane, but the Belt shows no evidence of extensive erosion. No fossils were seen in the Belt rocks.

The Big Snowy Mountains have never been mapped geologically, and the discovery of Belt strata in them extends the known area containing Algonkian strata forty miles farther east than hitherto reported.

O. W. FREEMAN

STOCKTON, CALIF.

## THE SCALES OF THE FOSSIL FISH EOBRYCON

OWING to the remarkable distribution of the Characinid fishes in the neotropical and ethiopian regions and consequent questions as to their origin and migrations, any scrap of information concerning fossil forms is of value. In 1898 Dr. A. S. Woodward described and figured *Tetragonopterus avus* from the Tertiary of São Paulo, Brazil. He considered that it might belong to the subgenus *Hemibrycon*, which is now considered a quite distinct genus. However, in 1907 Jordan made it the type of a new genus *Eobrycon*. In 1920 Dr. Eigenmann sent me a specimen, lacking the head, for examination. I found that the scales were exactly those of *Salminus*, and I think the fish must be placed in that vicinity. In his very excellent work on the fishes of western South America, just published by the Carnegie Museum, Dr. Eigenmann, in accordance with most ichthyologists, neglects to use or refer to the finer characters of the scales. I venture to predict that the time will come when scale-characters will be considered more valuable for generic diagnosis among the Characidæ or Characinidæ than the presence of an adipose fin or the completeness of the lateral line. More valuable because more constant and characteristic of natural divisions.

T. D. A. COCKERELL

UNIVERSITY OF COLORADO
JANUARY 30, 1923

## SCIENTIFIC BOOKS

### LOFTFIELD ON STOMATA[1]

NOT since the appearance of Lloyd's "Physiology of Stomata" in 1908 has there appeared in America a book which has taken up the problems involved in the behavior of stomata on the broad and comprehensive scale, and as

[1] "The Behavior of Stomata." By J. V. G. Loftfield. Publication No. 314, Carnegie Institution of Washington. Pp. 104; 54 figures in text, 16 plates with 27 figures. Washington, D. C., 1921.

possibly related to agricultural and industrial practices, as does this publication. For many years there has been a growing demand for more accurate information regarding the inter-relations of stomatal activity and environmental conditions. This situation became particularly critical a few years ago in connection with studies of smelter smoke injury in various parts of the continent and that stimulus finally culminated in the investigations which Dr. Loftfield has reported in this book. Many field and garden crop plants were included in the investigations.

The author, using the methods of Lloyd with some modifications, in the first portion of the work brings out some rather striking results. The daily march of stomatal movement varies considerably from day to day, in fact is seldom identical on two successive days. He states that such variations are due to changes in water-content and weather. In nearly all cases stomatal opening is correlated with light under favorable conditions, but in some cases light seems to play little or no part as a control. An outstanding feature of this portion of the work is the report that some plants, such as the potato, tend to maintain open stomata at night under optimum conditions of water-content, and that the behavior of stomata in upper and lower surfaces is usually quite different. In general the stomatal movements of each plant follow a regular course under optimum conditions, a course which is modified as conditions depart from the more favorable.

Part II brings us face to face with the complex inter-relations of environmental and internal factors as related to stomatal behavior. The author seems particularly emphatic in his statements that no ordinary atmometer or evaporimeter yet devised can be used to measure at all accurately the effect upon the plant of all of the factors concerned in evaporation. This may come as a shock to some of the enthusiasts in the field of "atmometry." Wind was found to cause increases of transpiration unlike the increases of evaporation measured by atmometers.

Plants tend to show much less response to wind than do atmometers, but with a sudden high wind they often reveal greater response. All attempts to correlate evaporation from atmometers and from free-water evaporimeters with transpiration failed, and led the author to state that "Until an atmometer is devised which responds in the same manner and degree to each of the factors concerned, the ratio of transpiration to evaporation is meaningless." His work tends to support the contention that there is no warrant for the view that lack of agreement between stomatal movement and "relative transpiration" based upon evaporation from the porous-cup atmometer indicates that stomata are non-regulatory.

A reduction of light intensity to less than half (as measured by the "solio" photometer) is commonly necessary to produce any effect upon the stomata of plants growing in the open. When stomata are closing they are affected by decrease in light more rapidly than when they are opening. Stomata may open at night as a result of moonlight or a strong artificial light of much less intensity than one per cent. of the solar maximum. They open more readily toward morning than before midnight. This part of the work, on the whole, leaves one with a sense of incompleteness and confusion, although it serves to reopen many long debated problems, and to contribute many additional data to indicate that it will be many years yet before we are provided with an adequate and comprehensive body of dependable facts and principles relative to the effects of habitat factors and plant development upon stomatal behavior.

The concluding part of the book records some interesting studies of the effect of stomatal movement upon transpiration, a favorite topic for ecological investigations. The author presents data which lead him to conclude that stomata *do regulate the water-loss from plants*, and so to question seriously the value of the work of Lloyd. He demonstrates the reasons for this notable lack of agreement and points out that Lloyd's evidence that stomata are non-regulatory is vitiated by his use of potometers to measure the water-loss of field plants. However, a careful perusal of the present text leaves the reaction that Loftfield's "evidence" upon the basis of which he summarily disposes of the potometer method is rather meager, especially as compared to that presented by Lloyd.

The author's opinion as to the regulatory rôle of stomata is nicely put in the concluding

statement: "Although the factors concerned in evaporation have great influence upon evaporation, this influence is definitely controlled by the stomata. When the stomata are wide open or nearly wide open, transpiration is the result of the action of the factors of evaporation alone, since the stomata in nowise interfere with the action. As the stomata close, the influence of the factors is lessened, but until closure has reduced the apertures to fifty per cent. or less, stomatal regulation is still largely overshadowed by the control exerted by them. When closure is almost complete, the regulation of water-loss by the stomata is very close and the effect of the factors overshadowed by the effect of even very small changes of the opening." This is, of course, quite different from the conception of "regulation" of some physiologists when they have attempted to compare the stomata-transpiration complex with the mechanism which rather effectively controls or "regulates" the speed of an engine under a variation of load.

The plates showing the features of the stomata in various plants under various conditions should receive special mention. The micro-photographs are arranged radially in such a manner as to show the condition of the stomata in upper and lower epidermis, especially the degree of opening, at each hour of a twenty-four hour day, together with curves for sunlight, temperature and humidity plotted toward the center of the circular figure. This commendable method enables one to compare readily the condition of the stomata in upper or lower epidermis at different hours of day or night and as related to the light, temperature and humidity values.

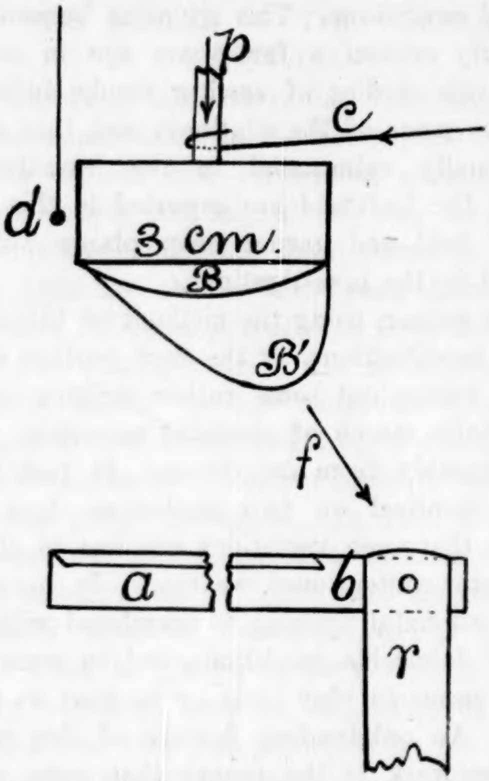
Loftfield's book is very stimulating, on the whole. It must be in the hands of every investigator working on problems in which stomatal behavior is involved.

RAYMOND J. POOL

## SPECIAL ARTICLES

### SPARKLESS SPARKS[1]

1. The endeavor to take away all the internal pressure (measured by the U-tube interferometer as in the preceding paper) from the soap bubble by charging it electrostatically, does not usually succeed unless the bubble is well anchored; otherwise the lower end is apt to break apart and fly off along the lines of force. A wide blower (say 3 cm. in diameter) as in the figure, with but a small segment of bubble $B$




projecting, is satisfactory. The initial pressures are thus reducible to .04 mm. of Hg, so that with flattish bubbles I have actually obtained negative pressures within, on charging.

The charged bubble usually takes an oblique oval figure, $B'$, being drawn out along the incidental lines of force $f$. This expansion, on very slowly increasing the potential, reaches a maximum, after which the bubble suddenly, in fact spasmodically, jerks back from $B'$ to $B$, remaining intact. With the same bubble a succession of 10-40 spasms may be easily obtained, at the end of which the bubble bursts. A pitch ball, $p$, near the metallic holder shows a definite but only very slight diminution of obliquity at each spasm. An adapted aluminum electroscope (right angled strip of aluminum, say 8 inches long, .03 mm. thick, flexible at $b$, appressed against a hacksaw blade and clutched by the hard rubber stem $r$) placed below $B'$, indicates a marked increment of potential, even at the least spasm of the bubble, from the beginning up to the maximum. With each such case, therefore, there is partial discharge, an outrush or ions, or an intermittent current. A few of the lines of force break loose and slide off.

[1] Advance note, from a Report to the Carnegie Institution of Washington, D. C.

2. As I understand the phenomenon, it is near the tip, $B'$, that the surface tensions acting with a component inward are first balanced by the electric pressure $2\pi\sigma^2$ outward. The application of the latter is strictly on the outer surface. Hence the surface layer of molecules is successively slid toward the point and then stripped off, until after ten or more repetitions, the remaining tissue is so thin that it breaks. This ionized molecular exfoliation, which takes place entirely without light effects even in the dark, may be referred to as in the caption.

In the beginning, when the bubble is thick at the bottom, holding a drop, etc., the first faint sparks imply an internal pressure reduction of less than 25 dynes/cm$^2$. At the end, when the bubble is possibly thinnest at the bottom, the pressure reduction is usually about 55 dynes/cm$^2$, and it is here that the surface tension proper competes with the electric pressure. If the pressure to produce a spark be estimated at 68 dynes per cm$^2$, the lines would seem to break off, to this extent, more easily from a liquid than from a solid surface; but in view of the varied curvature of the bubble, it is difficult to ascertain the distribution of the contending forces. The difference of capillary and electrical pressure only must be constant and it is rather remarkable that the two data given are so near together.

Carl Barus

Brown University,
Providence, R. I.

## THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

### REPORT OF THE TREASURER FOR 1922

Accepted by the Council, A. A. A. S., at Cambridge, Massachusetts, December 26, 1922

To the Council of the American Association for the Advancement of Science:

Gentlemen:

In conformity with article 15 of the constitution and by direction of the council, the treasurer has the honor to submit the following report for the period December 20, 1921, to September 30, 1922. This period covers the time necessary to comply with the new arrangement for the fiscal year of the association. Henceforth the fiscal year of the treasurer will begin on October 1 and end on September 30.

The total of cash receipts during the period is $4,803.14. Disbursements made in accordance with directions of the council amounted to $4,720.10.

The total amount of funds of the association, consisting of cash, cost value of securities purchased, and appraised value of securities received from the Colburn estate is $121,414.77.

A detailed statement is appended.

(Signed) ROBERT S. WOODWARD,
*Treasurer*

Washington, D. C.
September 30, 1922.

TREASURER'S CASH STATEMENT

December 20, 1921 to September 30, 1922

*Receipts*

| | | |
|---|---|---|
| December 20, 1921, balance from last report | | $ 5,585.90 |
| Interest from securities | $ 4,772.13 | |
| Interest from bank balance | 31.01 | |
| | | 4,803.14 |
| | | $10,389.04 |

*Disbursements*

| | | |
|---|---|---|
| Grants: | | |
| B. E. Livingston, permanent secretary (for Dr. Greenman) | $ 500.00 | |
| A. W. Smith | 150.00 | |
| L. R. Ingersoll | 150.00 | |
| F. C. Blake | 150.00 | |
| A. W. Rowe | 250.00 | |
| Harold Hibbert | 200.00 | |
| William C. Rose | 100.00 | |
| W. Tyler Olcott, Secretary | 200.00 | |
| Caroline E. Furness | 100.00 | |
| Herman J. Muller | 250.00 | |
| S. O. Mast | 200.00 | |
| Ralph E. Benedict | 125.00 | |
| Fred T. Rogers | 200.00 | |
| Frank P. Knowlton | 200.00 | |
| Frank H. Hartman | 150.00 | |
| Sebastian Albrecht | 100.00 | |
| Otis F. Curtis, Treasurer | 250.00 | |
| John T. Buchholz | 125.00 | |
| August F. Foerste | 150.00 | |
| F. Canu | 250.00 | |
| Raymond Dodge | 400.00 | |
| Franklin O. Smith | 300.00 | |
| | | $ 4,500.00 |
| Two life memberships from Jane M. Smith Fund | | 200.00 |
| Rental of safe deposit box | | 20.00 |
| Foreign exchange | | .10 |
| | | $ 4,720.10 |
| Cash in banks: | | |
| Fifth Avenue Bank | $ 4,397.60 | |
| U. S. Trust Company | 1,271.34 | |
| | | 5,668.94 |
| | | $10,389.04 |

TREASURER'S BALANCE SHEET

September 30, 1922

*Assets*

| | |
|---|---|
| Investments: | |
| Securities (Exhibit A) | $121,414.77 |
| Current Assets: | |
| Cash in bank | 5,668.94 |
| | $127,083.71 |

*Liabilities*

| | | |
|---|---|---|
| Funds and Accumulations: | | |
| Life, sustaining members and patrons* | $ 29,500.00 | |
| Jane M. Smith | 5,000.00 | |
| W. Hudson Stephens | 4,381.21 | |
| Richard T. Colburn | 77,755.74 | |
| Accumulated income invested in securities | 4,777.82 | |
| | | $121,414.77 |
| Unappropriated interest | | 5,668.94 |
| | | $127,083.71 |

SCHEDULE OF SECURITIES
(Exhibit A)

| *Par Value* | | *Purchase Value* |
|---|---|---|
| $ 10,000 | Chicago and Northwestern Railway Co. General Mortgage 4 per cent. bonds, due 1987 | $ 9,425.00 |
| $ 10,000 | Atchison, Topeka and Santa Fe Railway Co. General Mortgage 4 per cent. bonds, due 1995 | 9,287.50 |
| $ 10,000 | Great Northern Railway Co. First and refunding mortgage 4.25 per cent. bonds, due 1961 | 10,050.00 |
| $ 10,000 | Pennsylvania Railroad Co. Consolidated mortgage 4.5 per cent. bonds, due 1960 | 10,487.50 |
| $ 10,000 | Chicago, Burlington and Quincy Railroad Co. General mortgages 4 per cent. bonds, due 1958 | 9,350.00 |
| $ 10,000 | Union Pacific Railroad Co. first lien and refunding mortgage 4 per cent. bonds, due 2008 | 9,012.50 |
| $ 10,000 | Northern Pacific Railway Co. prior lien railway and land grant 4 per cent. bonds, due 1997 | 9,187.50 |
| $ 10,000 | New York Central and Hudson River Roalroad Co. 3.5 per cent. bonds, due 1997 | 8,237.50 |
| 100 | U. S. First Liberty Loan Bonds | 91.25 |
| 10,500 | U S. Second Liberty Loan Bonds | 10,172.36 |
| 2,000 | U. S. Third Liberty Loan Bonds | 2,000.00 |
| 2,000 | U. S. Fourth Liberty Loan Bonds | 2,000.00 |
| 6,500 | U. S. Victory Liberty Loan Bonds | 6,373.66 |
| | | $ 95,674.77 |
| | *Bonds from Colburn Estate* | |
| 20,000 | Acker, Merrall and Condit Co. debenture 6 per cent. bonds | 13,600.00 |
| 7,000 | Buffalo City Gas Co. first mortgage 5 per cent. bonds | 1,540.00 |
| 8,000 | Park and Tilford Co. sinking fund debenture 6 per cent. bonds | 6,400.00 |
| 42,000 | Pittsburgh, Shawmut and Northern Railroad first mortgage 4 per cent. bonds, due February 1, 1952 | 4,200.00 |
| | | $ 25,740.00 |
| $173,500 | | $121,414.77 |

*The records show this item of $29,500 as made up of 438 life memberships of $50 each, 16 life memberships of $100 each, and 6 sustaining memberships of $1,000 each.—B. E. L.

All of the above named securities, except those from the Colburn estate, are registered in the name of the association.

AUDITOR'S REPORT

I certify that I have audited the accounts of the treasurer of the American Association for the Advancement of Science for the period December 20, 1921 to September 30, 1922; that the securities representing the investments of the association have been exhibited and verified; with the exception of the P. S. and N. R. R. bonds which were represented by a receipt from the Columbia Trust Company of New York, and a $100 United States bond represented by a receipt from the United States Treasury Department, for title transfer, and that the income therefrom has been duly accounted for.

The financial statements accompanying the treasurer's report are in accord with the books of the association and correctly summarize the accounts thereof.

(Signed) ROBERT B. SOSMAN,
*Auditor*

Washington, D. C.
December 12, 1922.

TREASURER'S REPORT ON AGGREGATE RECEIPTS AND DISBURSEMENTS SINCE AUGUST, 1894

TO THE COUNCIL OF THE
AMERICAN ASSOCIATION FOR THE
ADVANCEMENT OF SCIENCE.

Gentlemen:

Supplementing my report of September 30, 1922, I beg to state that interest collections since September 30, 1922 (date of report), amount to $1,009.38. This amount added to collections reported in statement of September 30 gives a total collection of $5,812.52 during the year.

An aggregate statement of receipts and disbursements from August 21, 1894 to September 30, 1922 is appended. This statement shews collections from all sources amounting to $161,940.76 and disbursements amounting to $162,123.61, of which $121,414.77 represents cost of invested funds.

Respectfully submitted,

(Signed) ROBERT S. WOODWARD,
*Treasurer*

Washington, D. C.
December 20, 1922

*Receipts*

August 21, 1894 to September 30, 1922

| | | |
|---|---|---|
| August 21, 1894, cash on deposit, State Bank Safe Deposit Co., Boston | $ 5,564.48 | |
| Cambridge Savings Bank | 287.31 | |
| | | $ 5,851.79 |
| Collections: | | |
| Interest on securities | 33,901.10 | |
| Interest on bank deposit | 11,838.71 | |
| Life memberships | 19,180.00 | |
| Subscriptions, gifts and patrons | 4,467.00 | |
| Pasteur fund | 100.00 | |
| Transferred from funds Permanent Secretary by order of council | 5,000.00 | |
| Research funds | 87,178.95 | |
| Revertments | 275.00 | |
| | | $161,940.76 |
| | | $167,792.55 |

*Disbursements*

August 21, 1894 to September 30, 1922

| | | |
|---|---|---|
| Grants | $ 29,741.45 | |
| Life memberships | 8,300.21 | |
| Jane M. Smith fund | 1,450.00 | |
| Securities | 121,414.77 | |
| Purchased interest | 826.58 | |
| Rental safe deposit box | 90.60 | |
| Pasteur and other funds | 300.00 | |
| | | $162,123.61 |
| Cash in Banks: | | |
| Fifth Avenue Bank of New York | $ 4,397.60 | |
| U. S. Trust Company of New York | 1,271.34 | |
| | | $ 5,668.94 |
| | | $167,792.55 |

FINANCIAL REPORT OF THE PERMANENT SECRETARY FOR THE FISCAL YEAR, 1922

October 1, 1921 to September 30, 1922

*Receipts*

| | | |
|---|---|---|
| To balance from last account: | | |
| Checking account | $ 5,840.11 | |
| Savings account | 4,355.09 | |
| Petty cash | 7.81 | |
| | | $10,203.01 |
| To receipts from members: | | |
| Annual dues, previous to 1921 | $ 168.93 | |
| Annual dues, 1921 | 887.50 | |
| Annual dues, 1922 | 50,764.69 | |
| Annual dues, 1923 (paid in advance) | 363.00 | |
| Entrance fees | 1,204.87 | |
| Life membership fees | 1,500.00 | |
| Associate fees | 1,150.39 | |
| | | $56,039.38 |
| To other receipts: | | |
| From treasurer's office: | | |
| For life members' journal subscriptions | $ 1,029.00 | |
| Special grant appropriation | 500.00 | |
| Sale of publications | 770.00 | |
| Postage, exchange, overpayments, etc | 706.23 | |
| Interest on bank account | 142.59 | |
| | | $ 3,147.82 |
| Total | | $69,390.21 |

*Disbursements*

| | | |
|---|---|---|
| By publications: | | |
| Science Press | | $32,161.46 |
| By divisions, local branch and academy expenses: | | |
| Divisions | $ 1,275.00 | |
| State College (Pa.) local branch | 52.00 | |
| Remitted to affiliated academies on account of affiliation arrangements | 1,328.00 | |
| | | $ 2,655.00 |
| By expenses, general secretary's office | | 160.95 |
| By expenses, permanent secretary's Washington office: | | |
| Salary, permanent secretary | $ 2,500.00 | |
| Salary, assistant secretary | 1,000.00 | |
| Salary, executive assistant | 2,610.00 | |
| Usual clerical help | 2,230.00 | |
| Office and addressograph supplies | 222.47 | |
| Printing and stationery | 1,791.68 | |
| Telephone and telegraph | 256.28 | |
| Travel expenses | 1,919.07 | |
| Postage (billing and correspondence) | 769.23 | |
| Express | 52.35 | |
| Miscellaneous | 326.40 | |
| | | $13,677.48 |
| By expenses, circularization: | | |
| Affiliated societies and *American Men of Science* | $ 2,124.04 | |
| Medical men (New England) | 682.82 | |
| Local committee, Toronto meeting | 188.78 | |
| | | $ 2,995.64 |
| By expenses, Toronto meeting: | | |
| Travel expenses, W. Bateson | $ 300.00 | |
| Preliminary announcement | 1,124.11 | |
| Messenger service (biologists) | 16.50 | |
| Refund for expenses incurred by section secretaries | 134.29 | |
| Miscellaneous | 21.50 | |
| | | $ 1,596.40 |
| By miscellaneous expenses: | | |
| Refunds on account of overpayments | $ 427.73 | |
| Bad checks | 10.25 | |
| Summarized proceedings and membership list (vol. 67-73), 1921 | 5,430.43 | |
| Life membership fees | 2,600.00 | |
| Salt Lake City meeting | 450.32 | |
| Committee on grants for research | 48.47 | |
| Conference on Federation of Biological Societies, at Woods Hole, Massachusetts | 100.00 | |
| | | $ 9,067.20 |
| Total disbursements | | $62,314.13 |

| | | | |
|---|---|---|---|
| To new balance: | | | |
| Checking account | | $ 1,078.40 | |
| Savings account | | | |
| Emergency fund | $4,497.68 | | |
| Publication fund (for proceedings) | 1,500.00 | | |
| | | 5,997.68 | |
| | | | 7,076.08 |
| Total | | | $69,390.21 |

AUDITOR'S REPORT

Mr. Burton E. Livingston,
Permanent Secretary,
American Association for the Advancement of Science,
Washington, D. C.

Dear Sir:

Having been appointed auditor for the association for the year 1922, I have employed Mr. W. R. Gallaher, an accountant at the Interstate Commerce Commission, to go over the accounts of the permanent secretary for the year ending October 1, 1922. He makes the following report:

November 17, 1922.

This is to certify that I have carefully examined the records of all receipts and disbursements, in currency, checks, etc., of the permanent secretary's office of the American Association for the Advancement of Science for the year ending October 1, 1922, and have found the records correctly kept. Proper vouchers were shown for all disbursements.

(Signed) W. R. GALLAHER,
*Examiner of Accounts.*

I have reason to believe that Mr. Gallaher is an experienced and reliable accountant and that the above statement is a dependable report on the state of the accounts which were audited.

Very truly yours,

(Signed) ROBERT B. SOSMAN,
*Auditor*

Washington, D. C.
1 December, 1922

NOTE ON THE PERMANENT SECRETARY'S FINANCIAL REPORT

It is to be noted that a balance of $10,203.01 was carried forward from the fiscal year 1921 and that the corresponding balance at the end of the fiscal year 1922 is $7,076.08. The operations of the last year have therefore resulted in a decrease in the balance, amounting to $3,126.93. In this connection, however, it is to be noted also that the cost of printing the 1921-volume of "Summarized Proceedings and Membership List" was all met from the current funds of the fiscal year just ended, although none of this expense is properly chargeable to that year. The cost of printing the proceedings volume is shown as $5,430.43, which is greater by $2,303.50 than the amount ($3,126.93) by which the balance was decreased as above mentioned. From these considerations it appears that the decreased balance is due simply to the fact that the cost of printing the volume (properly chargeable against the preceding seven years and not to the year 1922 at all) has been wholly paid from the current funds for 1922. The 1922 balance of income above *current* expenses at the end of the fiscal year 1922 is really $7,076.08 *plus* $5,430.43, or $12,506.51, which represents an *increase* in the current balance amounting to $2,303.50.

A recurrence of this contingency is now being guarded against by the accumulation of a publication fund, to be formed by setting aside about $1,000 from the current funds each year, and it is planned that this fund will be sufficient to cover the cost of the next proceedings volume, to be published in 1925. At the end of the fiscal year 1922 the publication fund amounted to $1,500, and this has subsequently been increased to $2,500 by the setting aside of $1,000 from the current funds for 1923.—*B. E. L.*

BUDGET OF PROSPECTIVE EXPENDITURES

By the Permanent Secretary's Office, for the fiscal year 1923

| | |
|---|---|
| Journal subscriptions | $32,500.00 |
| Divisions | 1,300.00 |
| Local Branch | 50.00 |
| Academies | 1,350.00 |
| Salaries: Permanent secretary | 2,500.00 |
| Assistant secretary | 1,000.00 |
| Executive assistant | 2,700.00 |
| Clerical help | 2,280.00 |
| General secretary's expenses | 250.00 |
| Travel expenses | 2,000.00 |
| Office and addressograph supplies | 225.00 |
| Stationery and printing | 2,000.00 |
| Telephone and telegraph | 275.00 |
| Postage (billing, correspondence) | 800.00 |
| Express | 50.00 |
| Annual meeting | 1,500.00 |
| Circularization | 1,500.00 |
| Life membership fees, to treasurer | 1,000.00 |
| Miscellaneous | 1,614.00 |
| Committee on grants | 50.00 |
| Exchange on checks | 33.00 |
| Transfer to publication fund for Proceedings volume | 1,000.00 |
| Transfer to general emergency fund (interest on savings bank account for preceding year) | 181.00 |
| Total | $56,158.00 |